Re: 3d 157914

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May 2, 1991

21

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Re: Salford Quarry - Preliminary Listing of General Response Actions and Boron Ground Water Treatment Technologies

Dear Mr. Lee:

As discussed at our April 3 meeting with Ms. Gerallyn Valls, who was then EPA's Remedial Project Manager for the Salford Quarry, this letter provides initial identification of potential General Response Actions for addressing the presence of boron in ground water and the landfill. Based on available data, and pursuant to the instructions of Ms. Valls at the April 3 meeting, boron is considered to be the primary substance of concern at the site. Consequently, ENVIRON's efforts to date have focused on reviewing specific treatment technologies for removal of boron from water. Our preliminary findings are summarized herein.

General Response Actions

Preliminary General Response Actions for ground water and the landfill at the Salford Quarry Site are presented in Tables 1 and 2, respectively. These tables were prepared assuming that the substance of concern is boron. General Response Actions for ground water include No Action, as required by the National Contingency Plan (NCP); Institutional Actions; Containment; Collection/Discharge; and Collection/Treatment/Discharge. At this time, General Response Actions for control of the landfill area include No Action, Institutional Actions, and Containment. Tables 1 and 2 also provide a preliminary listing of remedial technologies and process options associated with each General Response Action. Ground water treatment remedial technologies currently address the removal of boron only.

Boron Treatment Technologies

A preliminary review of potential treatment technologies for removal of boron from water has been conducted. This review included a literature search, vendor contacts, and personal communications with individuals who have expertise related to the treatment of boron in aqueous solutions. The attached reference list includes all references identified

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that pertain to removal of boron from water; however, only the most relevant references are discussed. Much of the information was extracted from abstracts obtained through Chemical Abstracts; cited articles not yet received have been requested. Potential treatment technologies identified in the scientific literature include ion exchange, reverse osmosis, coprecipitation, adsorption, liquid-liquid extraction, and distillation. These technologies are currently listed as ground water treatment process options in Table 1. A summary of our findings is presented below. In general, no commercially-available technologies were identified that have been demonstrated to be effective in removing boron from water on a large scale.

Ion Exchange

Some studies have concluded that boron can be removed from aqueous solutions using a strong base anion exchange resin (Kunin 1972; Lapp and Cooper 1976; Wong 1984). The media in which boron occurs usually has exceptionally high concentrations of dissolved salts. Strong base anion exchangers will remove all other anionic species, and can, consequently, render an ion exchange process uneconomical if boron is the only constituent which is to be removed (Kunin 1972; Lapp and Cooper 1976; Rohm and Haas 1989). To address these concerns, Rohm and Haas Company developed a boron-specific anion exchange resin (Kunin and Preuss 1964). This resin, available as Amberlite IRA-743, complexes with boron in the form of boric acid, borate or related species (Rohm and Haas 1989). Rohm and Haas Company had no knowled1ge of any industry using their Amerlite IRA-743 ion-exchange resin to remove boron from wastewater streams; however, Dow Chemical Company may use the resin for removal of boron from a magnesium chloride process stream (Dickert 1991). The exhausted resin is regenerated first with sulfuric acid and then with sodium hydroxide (Rohm and Haas 1989). Because chemical costs associated with the regeneration process may be prohibitive in some instances, research into the elimination of the caustic regeneration step has been conducted and has indicated that a 14% lowering of capacity can be expected (Roberts 1971; Rohm and Haas 1989).

All of the existing studies on boron removal by ion exchange that has been identified have focused on influent boron concentrations at or below approximately 10 ppm and solutions generally high in ionic strength (Rohm and Haas 1989; Wong 1984). One study sought to develop a resin that did not contain the basic amino group found in Amberlite IRA-743 (this would reduce the regeneration cost) and that could handle higher feed flow rates (Grinstead and Wheaton 1971). They concluded that the Rohm and Haas resin was the most effective resin for removal of boron. However, in a later study Wong (1984) found that a strong base anion exchnage resin exhibited a higher exchange capacity (0.36 lb boron/cu ft resin) than IRA-743 (0.125 lb boron/cu ft resin). Listed below are some factors relating to boron adsorption with this boron-specific resin:

- Favors dilute solutions (Ottinger et al. 1973);
- No interference due to the presence of other salts (Patterson and Minear 1973);
- May be subject to chemical and/or biological degradation (Roberts and Gressingh 1970);
- Low capacity (Rohm and Haas 1974);
- High operating costs (Ottinger et al. 1973);
- High initial cost (Lapp and Cooper 1976); and
- May be fouled by solids (Waggott 1969).

A patent, U.S. Patent 3,856,670, was issued to Occidental Petroleum Corporation for an anionic ion-exchange resin, which reportedly will selectively remove borates from water (Peterson 1975). It is not known whether this resin is commercially available.

Several ion exchange vendors (Matt-Son; AllTech; Mobile Water Tech; and Steelhead Specialty Minerals) were contacted for information concerning the use of ion exchange for boron removal. With the exception of Rohm and Haas, none of these vendors manufactures boron-specific resins nor has experience in treating boron-containing waters.

Reverse Osmosis

Removal of boron by reverse osmosis has been investigated for purification of potable water supplies and industry-specific uses. Both hollow fiber and spiral wound configurations have been tested (Folster et al. 1980). These studies generally evaluated boron influent concentrations below 1 ppm and generally achieved effluent concentrations of 0.1 ppm or less (Jarrett 1978; Foster et al. 1980; Argo 1984).

Boron removal by cellulose acetate membrane (CA) reverse osmosis is reported to be most efficient at pH 5, with removals of 38-60% (Cruver 1973). A cellulose acetate butyrate (CAB) membrane has been developed and studied for boron removal. In comparison with the more conventional CA membrane, the CAB membrane demonstrated a better rejection rate of uncomplexed boron (as boric acid), but yielded a lower permeate flux (Manjikian et al. 1970).

Vendors specializing in reverse osmosis applications (Western Filter; Membrex; Ion Pure Technologies, formerly owned by Millipore; and Cartwright Co.) were contacted regarding the use of reverse osmosis for removal of boron. None of these firms have direct experience in the removal of boron from water.

Coprecipitation

Studies conducted in the USSR, United Arab Republic, Japan, and the United States suggest that boron can be removed by coprecipitation with amorphous hydroxides such as aluminum (III) and iron (III) (Murakami 1965; Mun et al. 1969; McPhail 1970; Mun, Rodionova, and Kosenko 1971; Rodionova et al. 1971; McPhail, Page and

Bingham 1972; Sheremet'eva et al. 1972; Metwally, El-Damaty, and Yoursy 1974; Rodionova et al. 1974; Zhaimina, Balapanova, and Budeeva 1975; Zhaimina and Imanalieva 1975; Rodionova, Zhaimina, and Lukonina 1976; Nuryagdyev, Esenova, and Azarova 1977; Zhaimina, Balapanova, and Budeeva 1978; Ishibashi, Kaneda, and Nomura 1987). The effects of pH, salt species and strengths, and boron concentrations up to 5400 ppm boron have been addressed.

A patented French process fixes boron on an anionic exchange column; then elutes borate from the column with alkali. The alkaline solution is adjusted to a pH of 9.5, filtered, and mixed with $CaCl_2$ and H_2O_2 while maintaining a constant pH. After a 24-hour reaction/settling period, solids containing boron are removed and the process is repeated, if necessary. An alkaline solution containing 2600 mg/L of boron was reduced to 47 mg/L (Chauvet and Berton 1971). It is not known whether this procedure has been commercially applied.

Research has been conducted on lime precipitation of boric acid and borates. Experimental results suggest that removal efficiencies are below 25% (Waggott 1969; Roberts and Gressingh 1970). An alumina-lime-soda water treatment process has been shown to reduce influent boron concentrations of 1.7 ppm to 0.2 ppm (Nebgen, Shea, and Chiu 1972).

Adsorption

Various articles pertain to the removal of boron from aqueous solutions by adsorption. GAC has been reported to remove 90% of boron, regardless of the characteristics of the background solution, when the initial boron concentration is below 5 mg/L (Choi and Chen 1979).

The adsorption of boron from solution by magnesium oxide or other magnesia-containing sorbent has been researched (such as magnesite combined with slaked lime) (Shoikhet, Sologubenko, and Karasik 1961a, 1961b, 1964; Rza-Zade 1961; Shoikhet, et al. 1966; Krejcirik 1968). Influent concentrations of boron as high as 1200 mg/L and the properties of the magnesia-containing sorbent have been explored.

A Japanese patent describes a method for preparing activated carbon capable of adsorbing boron from solution (Sugasaka et al. 1975). The carbon is prepared such that insoluble iron hydroxides are adsorbed or deposited on it.

Dr. M. M. Ghosh, Professor of Civil Engineering at the University of Tennessee, has published extensively on inorganic adsorption and coprecipitation. While he does not have direct experience in adsorptive removal or coprecipitation of boron, he suggested that adsorption of boron onto activated alumina might be feasible. The mechanism of activated alumina adsorption is not well understood, however, and cannot be predicted.

Liquid-Liquid Extraction

Several patents exist for liquid-liquid extraction of boron. In the extraction process, a water insoluble polyhydroxy compound is dissolved in a suitable solvent which is immiscible with water and of different specific gravity. Boron is extracted from the aqueous solution into the solvent phase by complexation (Lapp and Cooper 1976). No information was provided concerning the efficiency of this technology.

Distillation

A distillation process has been patented for the removal of boron. Treatment of a liquid waste containing 21,000-22,000 ppm boron yielded 50-80 ppm of boron in the recondensed vapor. This water was subsequently passed through a 6-ft bed of ceramic Raschig contact rings, and the condensed vapor boron content was reduced to 2-3 ppm (Doeldner 1970).

In summary, six potential treatment technologies for removal of boron from aqueous solutions have been identified. No instances were discovered where boron is removed from wastewater streams on a large scale using any of these technologies. We will continue our identification and review of potential boron treatment technologies for ground water at the Salford Quarry.

Sincerely,

Bill Stone

William A. Stone, Jr.
Principal

WAS:sjb

ORIGINAL (Red)

TABLE 1
Salford Quarry Feasibility Study
List of Remedial Actions for Boron in Ground Water

Ground Water General Response Actions	Remedial Technology	Process Options	Description
No Action	None	Not applicable	No action
Institutional Actions	Access Restrictions	Deed Restrictions	Deeds for property in any area of influence would include restrictions on wells
	Alternate Water Supply	City water supply	Extension of existing municipal well system to serve residents in any area of influence
		New community well	New wells to serve residents in any area of influence
		Point-of-entry-treatment systems	Home treatment systems for removal of contamination, if any
	Monitoring	Ground water monitoring	Ongoing monitoring of wells to characterize the area of influence
Containment	Cap	Impermeable clay and soil cap	Upgrading and maintenance of existing impermeable cap of compacted clay covered with soil over areas boron disposal
		Asphalt cap	Spray application of a layer of asphalt over areas of boron disposal
		Concrete cap	Installation of a concrete slab over areas of boron disposal
		Multimedia cap	Clay and synthetic membrane covered by soil over areas of boron disposal
	Vertical barriers	Slurry wall	Trench around areas of contamination is filled with a soil (or cement) bentonite slurry
		Grout curtain	Pressure injection of grout in a regular pattern of drilled holes
		Vibrating beam	Vibrating force to advance beams into the ground with injection of slurry as beam is withdrawn

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TABLE 1
Salford Quarry Feasibility Study
List of Remedial Actions for Boron in Ground Water

Ground Water General Response Actions	Remedial Technology	Process Options	Description
	Horizontal barriers	Grout injection	Pressure injection of grout at depth through closely spaced drilled holes
		Block displacement	In conjunction with vertical barriers, injection of slurry in notched injection holes
Collection/ Discharge	COLLECTION		
	Extraction	Extraction wells	Series of wells to extract ground water
		Extraction/injection wells	Injection wells introduce uncontaminated water to the water table to increase the recovery of water containing boron by the extraction wells
	Subsurface drains	Interceptor trenches	Perforated pipe in trenches backfilled with porous media to collect water
	DISCHARGE		
	On-site Discharge	Deep well injection	Extracted water discharged to on-site deep well injection system
	Off-site Discharge	POTW	Extracted water discharged or transported to local POTW for treatment and/or disposal
		RCRA facility	Extracted water discharged or transported to a RCRA facility for treatment and/or disposal
Collection/ Treatment/ Discharge	COLLECTION	See Collection under "Collection/Discharge" above	
	TREATMENT		
	Physical/Chemical Treatment	Co-precipitation	Adsorption of boron onto metal or rare earth hydroxide precipitates

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ORIGINAL (Red)

TABLE 1
Salford Quarry Feasibility Study
List of Remedial Actions for Boron in Ground Water

Ground Water General Response Actions	Remedial Technology	Process Options	Description
		Neutralization	Addition of chemicals for pH adjustment (potentially required as treatment train component)
		Filtration	Water passes through a filter medium for solids removal (potentially required as treatment train component)
		Adsorption	Adsorption of boron onto adsorbents such as activated carbon, activated alumina, or magnesium oxide
		Reverse Osmosis	Separation of water from boron by filtering through a semipermeable membrane at a pressure greater than the osmotic pressure
		Ion exchange	Water is passed through a resin bed where boron is removed from water
		Liquid-liquid extraction	Boron is extracted from an aqueous solution into a suitable solvent by complexation
		Distillation	Boron is distilled in a patented process
	DISCHARGE		
	On-site Discharge	Surface recharge	Treated water reinjected into upper aquifer
		Deep well injection	Treated water discharged to on-site deep well injection system
	Off-site Discharge	POTW	Treated water discharged or transported to local POTW for additional treatment and/or disposal
		RCRA facility	Treated water discharged or transported to a RCRA facility for additional treatment and/or disposal
		Local surface water body	Treated water discharged to river or other surface water body not on site

Table 2
Salford Quarry Feasibility Study
List of Remedial Actions for Boron in Landfill Area

Source Area General Response Actions	Remedial Technology	Process Options	Description
No Action	None	Not applicable	No action
Institutional Actions	Access Restrictions	Deed restrictions	Deeds for property in any areas of influence would include restriction on land use
		Fencing	Expansion and/or maintenance of existing fence around landfill area to restrict public access to the site
Containment	Cap	Impermeable clay and soil cap	Upgrading and maintenance of existing impermeable cap of compacted clay and soil layers over areas of boron disposal
		Asphalt cap	Spray application of an impermeable layer of asphalt over areas of boron disposal
		Concrete cap	Installation of an impermeable layer of concrete over areas of boron disposal
		Multi-media cap	Construction of an impermeable clay and synthetic membrane covered by soil aver areas of boron disposal
	Horizontal Barriers	Grout injection	Pressure injection of grout at depth through closely spaced drilled holes
		Block displacement	In conjunction with vertical barriers, injection of slurry in notched injection holes
	SURFACE CONTROLS (runoff, run-on, sediment)		
	Runoff Controls	Collection/Discharge	Construction of dikes, berms, ditches and possibly pumps to collect runoff from the site for disposal (see disposal options under Ground Water Collection/Discharge General Response Action)

Table 2
Salford Quarry Feasibility Study
List of Remedial Actions for Boron in Landfill Area

Source Area General Response Actions	Remedial Technology	Process Options	Description
		Collection/Treatment/ Discharge	Construction of dikes, berms, ditches and possibly pumps to collect runoff from the site for treatment and disposal (see treatment and disposal options under Ground Water Collection/Treatment/Discharge General Response Action)
	Run-on Controls	Diversion	Grading and or construction of impermeable dikes and berms to divert "clean" surface water (run-on) upstream away from areas of boron disposal
	Sediment Controls	Revegetation	Plant growth in barren areas to provide sediment and dust control and prevent erosion and transport of material to and from areas of boron disposal.
		Silt fences (curtain barriers)	Surface construction of 1-2' vertical barriers to prevent erosion and migration of sediments and soil to and from areas of boron disposal

ORIGINAL (Red)

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